International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD)
ISSN (P): 2249-6866; ISSN (E): 2249-7978
Vol. 8, Issue 3, Jun 2018, 1-6
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•Journal Publications •Research Consultancy

EFFECTS OF KYE PROPERTIES, SHAPE AND LOCATIONS ON REINFORCED CONCRETE ARCHES BEHAVIOR

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ABSTRACT

An arch defined as a curved girder having convexity upwards and supported at its ends. The shape of the arch may be circular, elliptical or parabolic and sometimes it is made up by circular arcs of several and different radii or/and centers. It may be subjected to in- plane vertical, horizontal or even inclined loads. The arch carries compression loads, not tensile loads while the horizontal beam sustained tension and compression loads. In present experimental tests, five reinforced concrete arches are adopted and tested under central static loadings. The arches are different in compressive strength of flange and web, amounts of stirrups and the key connection configurations for the T – section reinforced concrete arches. The tests results showed that the presence of the CFRP not enough to re-strength of the reinforced concrete arch but need to extend the main reinforcements to the other segmental parts.

***KEYWORDS**: Reinforced Concrete Arches, Compressive Strength, Partial Interaction & Stirrups*

Received: Mar 04, 2018**; Accepted:** Mar 24, 2018**; Published:** Apr 27, 2018**; Paper Id.:** IJCSEIERDJUN20181

Original Article

INTRODUCTION

Arches define as a curved structural element was used in many different functions of engineering construction [1]. In 2000, Hutchinson [2], discussed analysis and design of segmental precast arches. Finite elements approach was adopted to build the models and applied specific loading up to the failure of arches. The analysis results indicated that the segmental arch and quick, flexible and economical that used in transportation projects. In 2005, Zhou et al [3], studied the shear strength of the segmental arch bridge. The parameters that adopted are joints in case of flat and keyed, single and multiple keyed in case of dry and epoxied joints under different stress levels and amount of epoxy. The test results compared with AASHTO and other design codes and criteria and founded that these relationships of shear regularly or frequently behave underestimated the shear strength that developed at joints as single and multiple keyed up to (40%) and overestimated in case of dry joints. In 2006, Voo [4], investigated the enhancement of the shear strength of I girder by used reactive powder concrete for the pre-stressed concrete girder. The silica fume was added to the mix design in different quantity as kg per one cubic meter (223, 221, 219 and 225). The test results showed that the presence of silica fume gave more girder strength capacity and enhanced in mechanical properties of concrete. In 2006, Cizmar et al [5], investigated the mechanical properties of reactive powder concrete that used in the construction of an arch bridge. Silica fume with density (2.23 gm/cm^3), and PH value (8.44) was used with other materials such as superplasticizer and steel fibers to produced reactive powder concrete. The analysis results indicated that the high compressive strength of reactive powder concrete leads to use this type in long span bridge. In 2007, Kim et al [6], studied by the numerical method to analyzethe joints between precast post-tensioned segments. The model was solved as nonlinearity material by a

computer program RCAHEST was a nonlinear finite element analysis program for analyzing reinforced concrete structures. The slip that developed at the joint interfaces was considered and taking into account when built the model. In 2012, Hua et al [7], studied the mechanical properties of reactive powder concrete. Silica fume was adopted with different quantities in additional of cement, fly ash and slag. The reactive powder concrete tested to determine the compressive strength, splitting tensile strength, modulus of rupture and modulus of elasticity. Test results showed that RPC has very high mechanical performance.

In present work, the parameters that taking into accounts are the compressive strength of concrete, the amounts of stirrups and the key configurations. The effects of partial interaction degree on reinforced concrete arch behavior as experimental tests are examined.

EXPERIMENTAL PROGRAM

The experimental program consisted of material mechanical properties, support and loading conditions and test methodology.

Mechanical Properties of Materials

The average of three specimens is adopted at (28) days at the time of tested specimens as cubes, cylinders, and prisms. The cement type is Ordinary Portland cement that mixed with the fine and coarse aggregate in which the maximum size of (4.75mm) and (10 mm) respectively. To enhance the compressive strength and tensile resistance of concrete, silica fume was added to the concrete mix. Two types of high strength concrete are adopted in which the mix design quantizes lists in Table (1).

Table 1: Mix Design Based on the Compressive Strength of Concrete

Materials	Compressive Strength (25 MPa)	Compressive Strength (50 MPa)	Compressive Strength (75 MPa)
Cement (Kg)	80	75	84
Fine aggregate	120	135	156
Coarse aggregate	240	150	120
Water (L)	36	30	24.6
Superplasticizer G51 (L)	-	1.5	7.8
Silica fume	-	4.5	11.25

Three specimens for each diameter of the reinforcement's bars that used to reinforced the concrete arches as top, bottom and stirrups are tested by taking specimen length (500 mm) as static yield stress, ultimate tensile strength, and Young's modulus, the tests result lists in Table (2).

Table 2: Properties of Steel Reinforcement

Nominal Diameter(mm)	Yield Tensile Strength f_y (MPa)	Ultimate Tensile Strength f_u (MPa)	E_s (MPa)
12	410	610	200000
10	405	596	200000

Supports and Loadings Conditions

All specimens have same boundary conditions as simply supported at the ends. The specimens are set up at (2100

mm) arch span and loaded with a central point load at the top face of the specimens. The applied load was distributed across the width of the specimen (line loading) by using a solid rod, as shown in Figure (1). The load was applied in specimens in successive increments, up to failure as load control.

Figure 1: Applied Loading Setup

Test Methodology

The total specimens as reinforced concrete arches are five specimens were tested and listed in Table (3). The arches specimens profile, configuration, and details showed in Figure (2).

Table 3: Specimens Details

Specimen Marks	Specimen Description	Flange Compressive Strength *fc'* (MPa)	Web Compressive Strength *fc'* (MPa)	Joint Configuration
AR1	Casting once	25	25	N/A
AR2	Composite arch	25	25	
AR3	Composite arch	50	25	
AR4	Composite arch	75	25	
AR5	Composite arch	75	25	

The specimens are classified into five specimens relay on the concrete type, segmental of arches and the spaces of strips. The height of arches for all the specimens is (500 mm) at the bottom face of the arch, the length of arches (2100 mm). The first specimen have the same compressive strength for web and flange, the others four composite arches differ in the concrete type of flange with (f_c') ranged as (25, 50 and 75 MPa) with (10 mm) diameter of stirrups at (150 mm) center to center. For all specimens except the control AR1, the concrete and reinforcement terminated at the joints so that there are no connections between the segmental parts except the CFRP that place at the junctions. The CFRP properties are SikaWrap – 300 C/60 with 9300 mm) in width and (0.166 mm) in thickness, (3900 MPa) as tensile strength, (230000 MPa) modulus of elasticity and (1.5%) elongation.

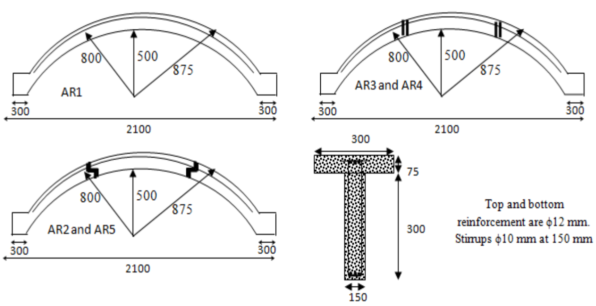

Figure 2: Arches Configuration and Geometry, All Dimensions in Mm

TESTS RESULTS

Five differences reinforced concrete arches that mentioned in Table (2) that subjected to static load up to failure. Figures (3) to (7) shows the specimens before and after the test. The mode of failure is flexural for specimen AR1 and shear for others at the joints. Figures (8) to (9) represents the full behavior of the load-deflections at arch center and at the quarter of the arches span respectively. The behavior of all specimens linear up to the first crack loadings and then the behavior become nonlinear so that the curve directed toward the horizontal axis because of the concrete become weak due to increasing in applied loading up to failure. Table (3) lists the summary of the tests results.

Figure 3: Specimen AR1 Before and After Test

Figure 4: Specimen AR2 Before and After Test

Figure 6: Specimen AR4 Before and After Test

Figure 7: Specimen AR5 Before and After Test

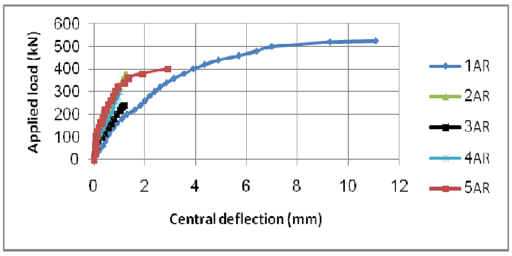

Figure 8: Load – Deflection Behavior at Center for All Specimens

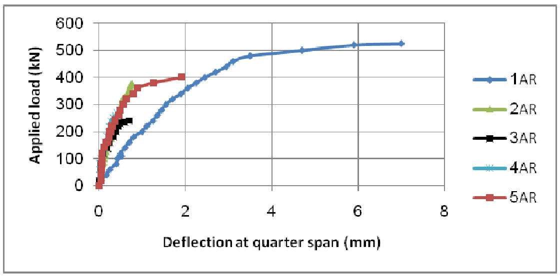

Figure 9: Load –Deflection Behavior at Quarter of Span for All Specimens

Table 4: Tests Results Summarized for all Specimens

Specimen Mark	First Cracks Load P_c (kN)	Deflection at First Cracks (mm)		Ultimate Load P_u (kN)	% of Change Related to Control Specimen	Deflection at Ultimate Load (mm)	
		Quarter span	Central			Quarter Span	Central
AR 1	105	0.45	0.53	525	0	7.00	11.10
AR 2	164	0.19	0.28	370	-29.52	0.75	1.21
AR 3	120	0.31	0.38	230	-56.19	0.70	1.10
AR 4	85	0.27	0.32	300	-42.86	0.51	0.95
AR 5	120	0.07	0.16	400	-23.81	1.94	2.90

DISCUSSIONS

The control specimen gave strength load capacity more than other specimens because casted at the same time and without joints. The strength capacity of specimen AR5 greater than AR2 because of the compressive strength of the flange more and also the deflection is less at the same of AR2. Similar reason for AR3 and AR2, also the capacity of AR5 greater

than AR4 because of the type of joint staggered that behaved better than the straight joint because of when the load increased the upper part of the arch rest on the lower parts that gave less deflection and more strength.

CONCLUSIONS

Based on the test results, following are the points that observed and concluded: the control reinforced concrete arch AR1 gave strength capacity more than other specimens. This is because of a continuous cast for all parts at the same time and the reinforcements continuous. Steeped key gave resistance and strength capacity better than the straight key because of there was decreased in shear stress and increased in shear friction (chair key). Steeped key gave decreased in deflections as compared with chair key because of each segment rest to another one that increased the resistance of the specimen. The compressive strength of concrete will effects on the behavior and strength of the reinforced concrete arches even when casted at different times. Deflections at the quarter and mid-span decreased with increase in compressive strength of concrete because of increase in modulus of elasticity of concrete. The presence of CFRP help the specimens to resists the externally applied load but not enough so that the main reinforcements must extend to the other segments. All specimens up to inflection point that represent the first crack behaved as linear and the curves inclined to the horizontal direction that represents the concrete become weak due to increase in cracks up to failure

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